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EXPANDING THE FRONTIERS OF SPACE ASTRONOMY

JWST Instrument Capabilities

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Space Telescope Science Institute

James Webb Space Telescope (JWST)

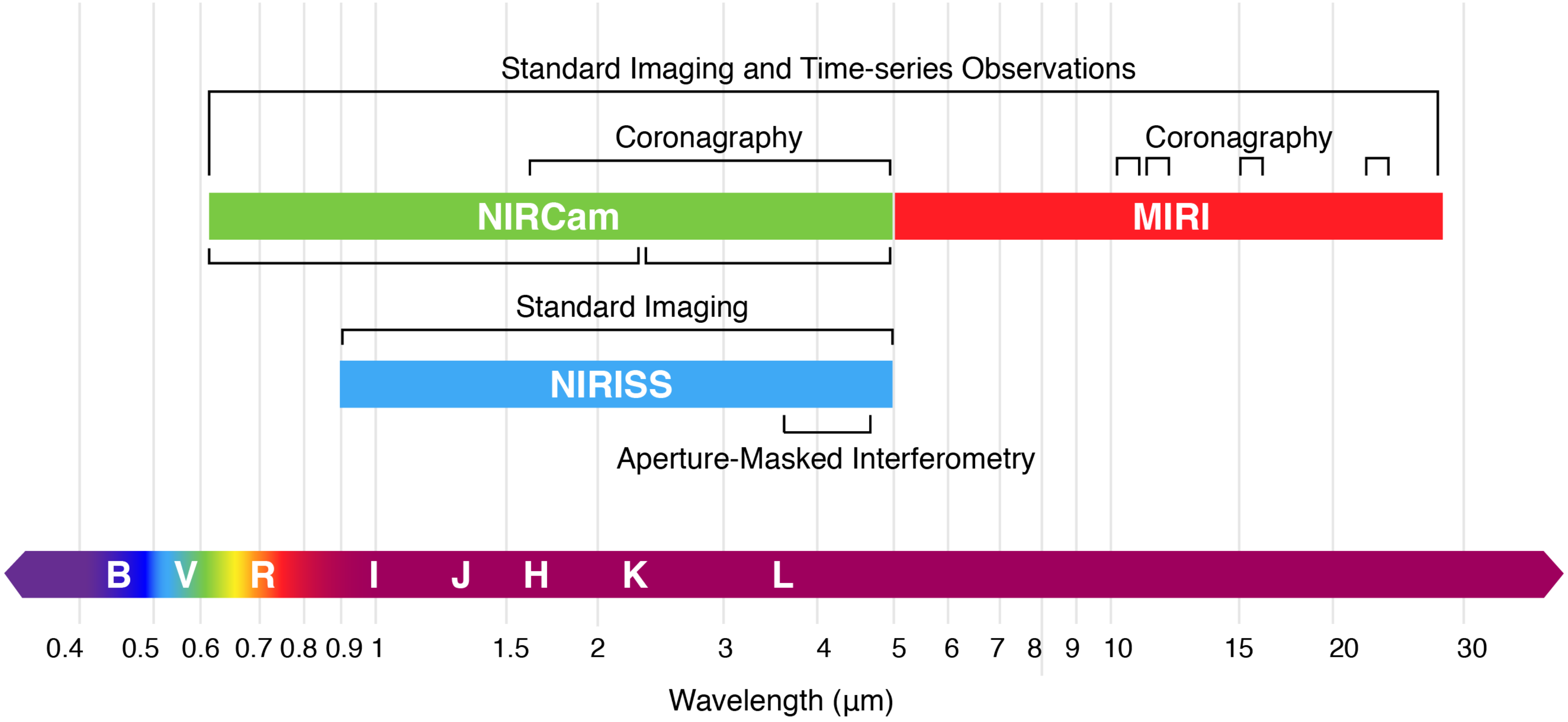
"Webb's infrared-detecting gaze will penetrate clouds of dust within our own galaxy to reveal previously hidden secrets, and reach back in space and time to view the very edge of the cosmos."

- Near Infrared Camera (**NIRCam, PI: M. Rieke**)
  - 0.6 – 5.0 μm
- Near Infrared Imager and Slitless Spectrograph (**NIRISS, PI: R. Doyon**)
  - 0.6 – 5.0 μm
- Near Infrared Spectrograph (**NIRSpec, PI: P. Jakobsen, Project Scientist: P. Ferruit**)
  - 0.6 – 5.3 μm
- Mid Infrared Instrument (**MIRI, European PI: G. Wright, Instrument Scientist: A. Glass, Science Team Lead: G. Rieke, JPL Instrument Scientist: M. Ressler**)
  - 4.9 – 28.8 μm

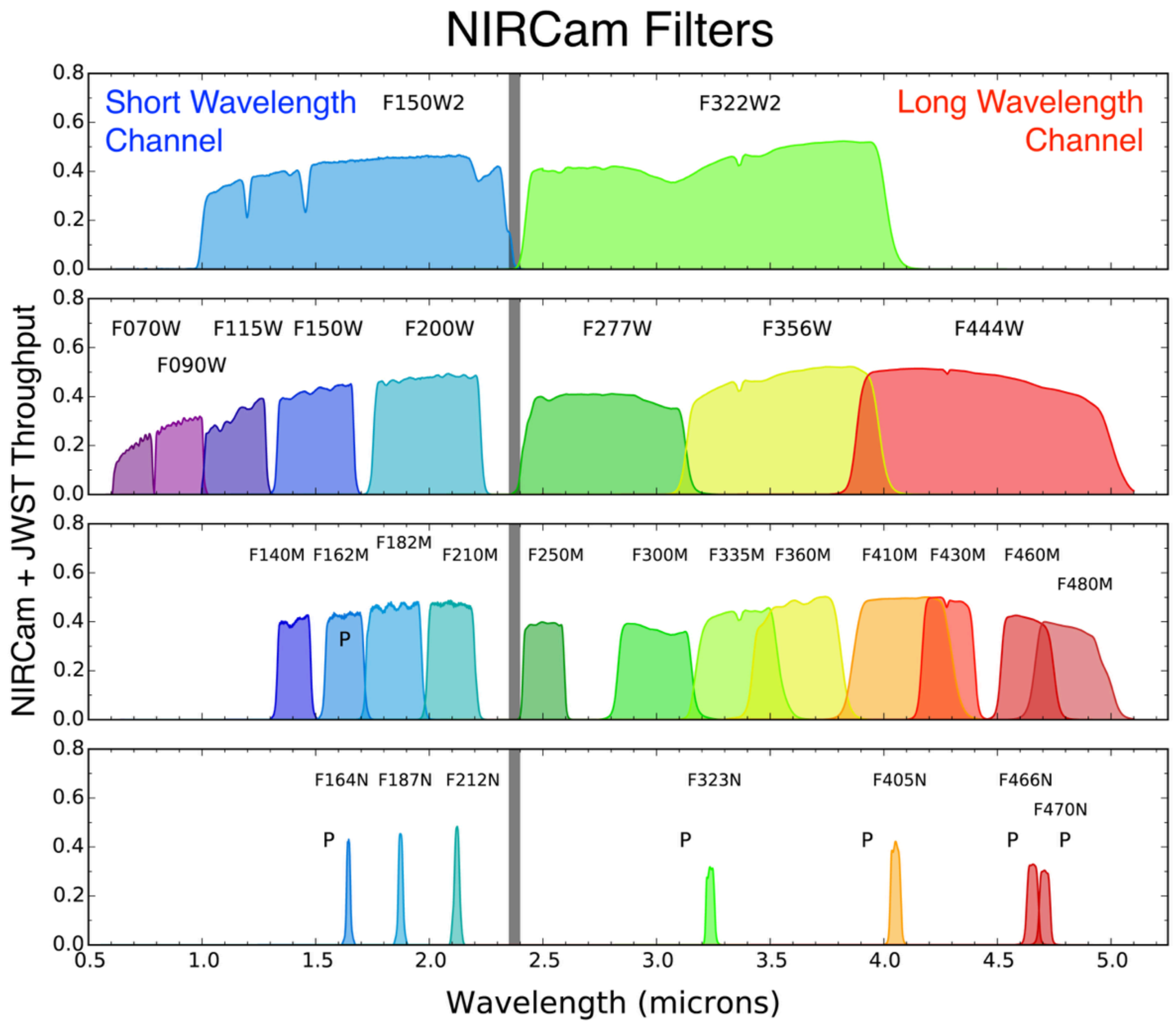
4 instruments → 18 observing modes

- Standard imaging & slit spectroscopy
- High contrast imaging: detect faint companion objects near bright host
- Wide field slitless ("grism") spectroscopy: dispersed spectrum of every object in field of view
- Multi-object spectroscopy: simultaneous spectroscopy of *known* sources in FoV
- Integral field unit spectroscopy: spatially resolved 2D spectra
- Time series observations: long, stable observations optimized for exoplanet transits
    - Imaging: detect secondary eclipses, assess planet/star flux
    - Spectroscopy: characterize exoplanet atmospheres

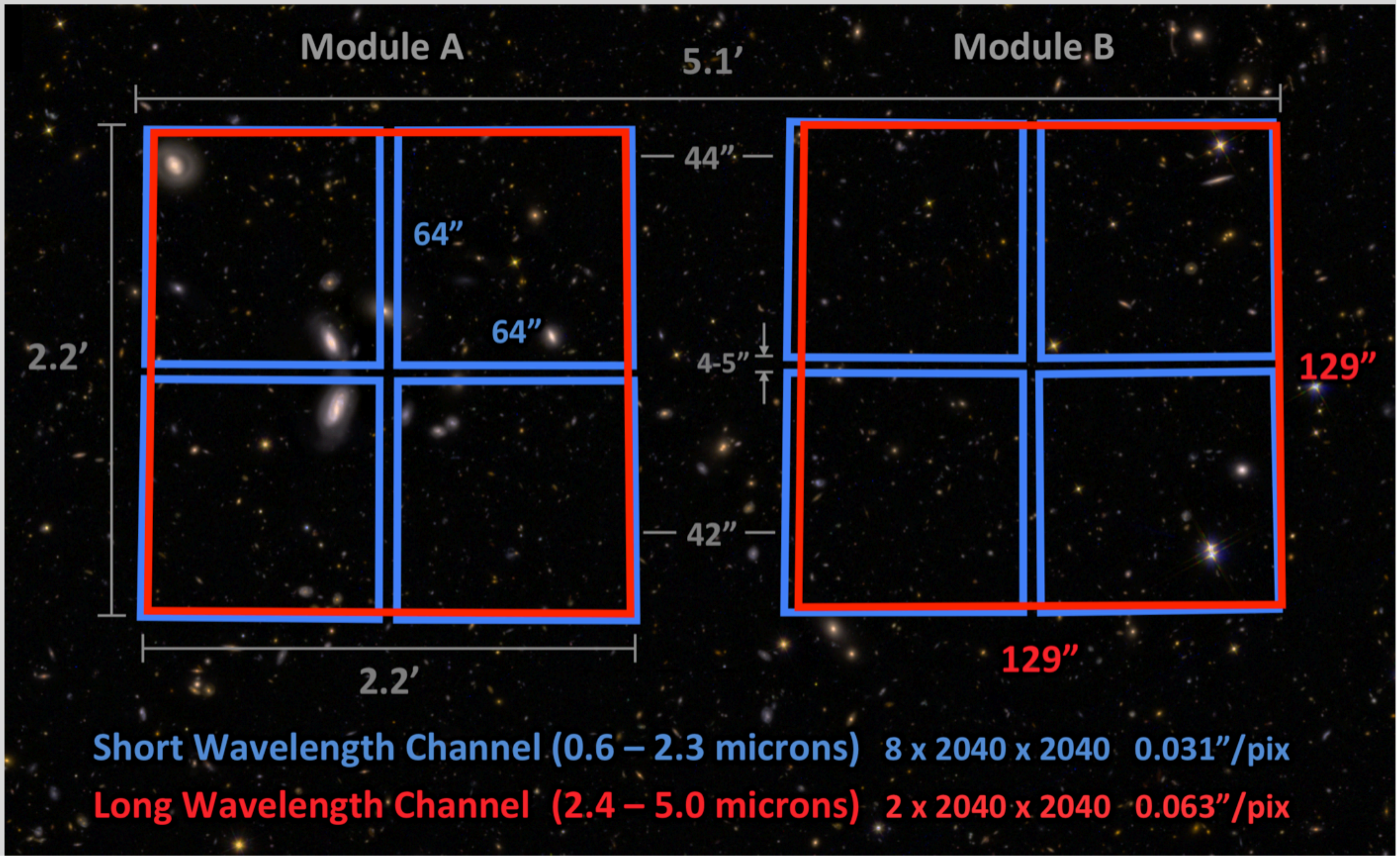
Comparison of JWST Instrument Capabilities: Imaging



Imaging: NIRCam (0.6 – 5.0 μm)



Imaging: NIRCam



Imaging: NIRCam

- Standard imaging: dithering *required*
    - fill gaps, mitigate flat field uncertainties, better sample PSF to improve resolution

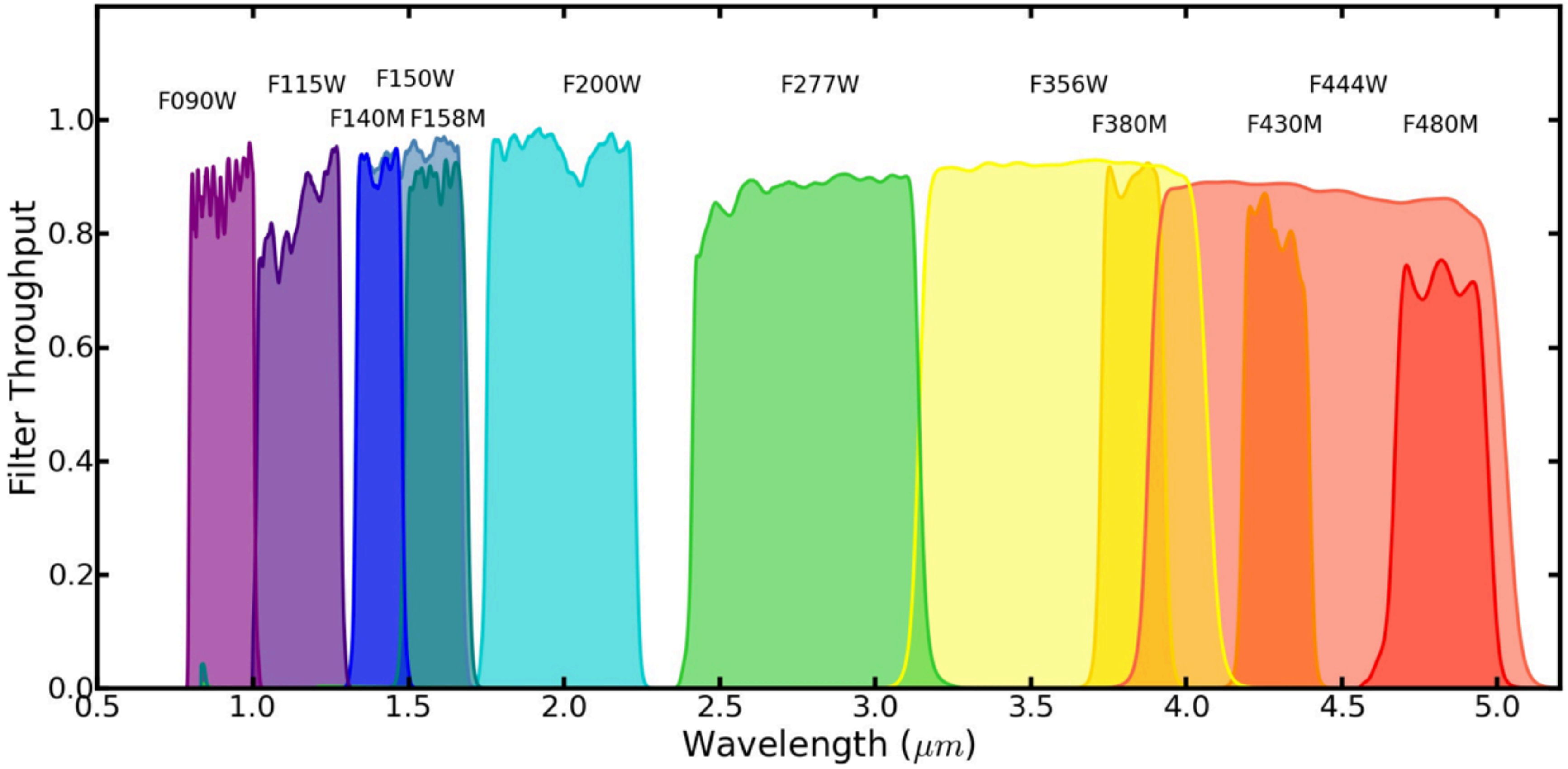
- Time Series Observations: dithering not permitted

➔ Stability essential for science return

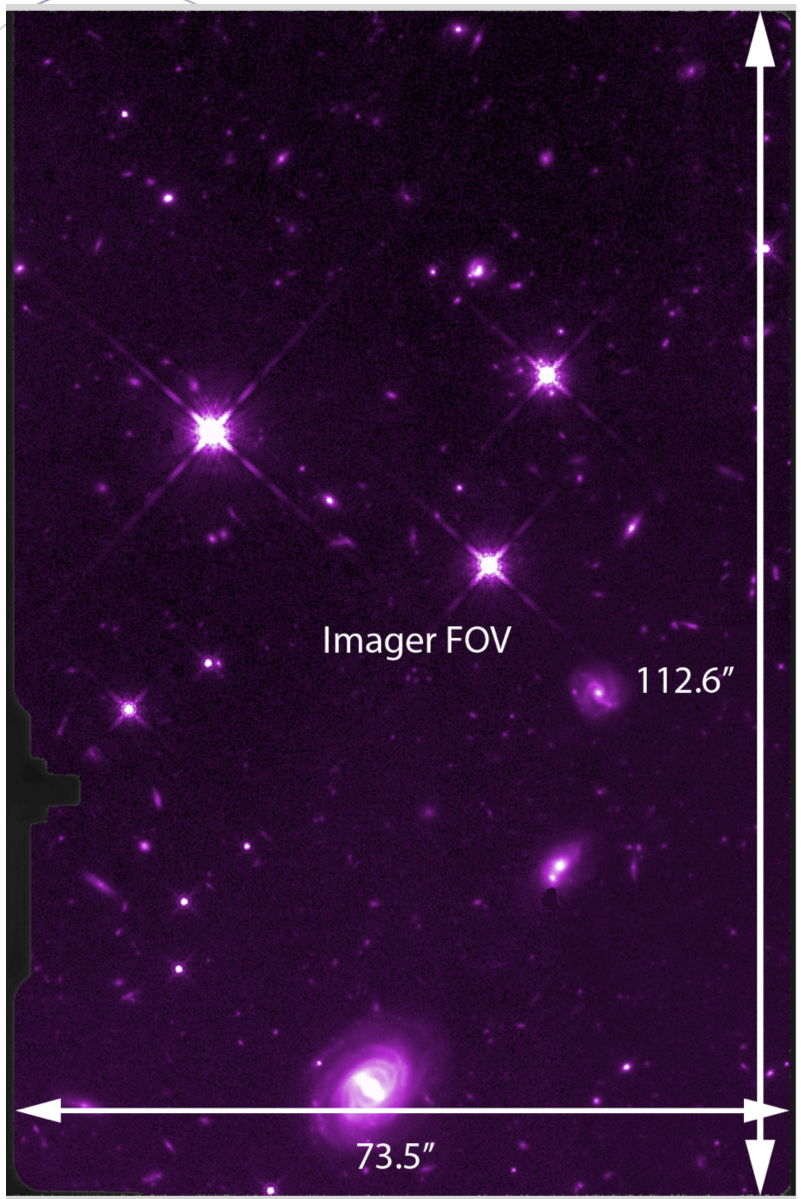
Imaging: NIRISS (0.8 – 5.0 μm)

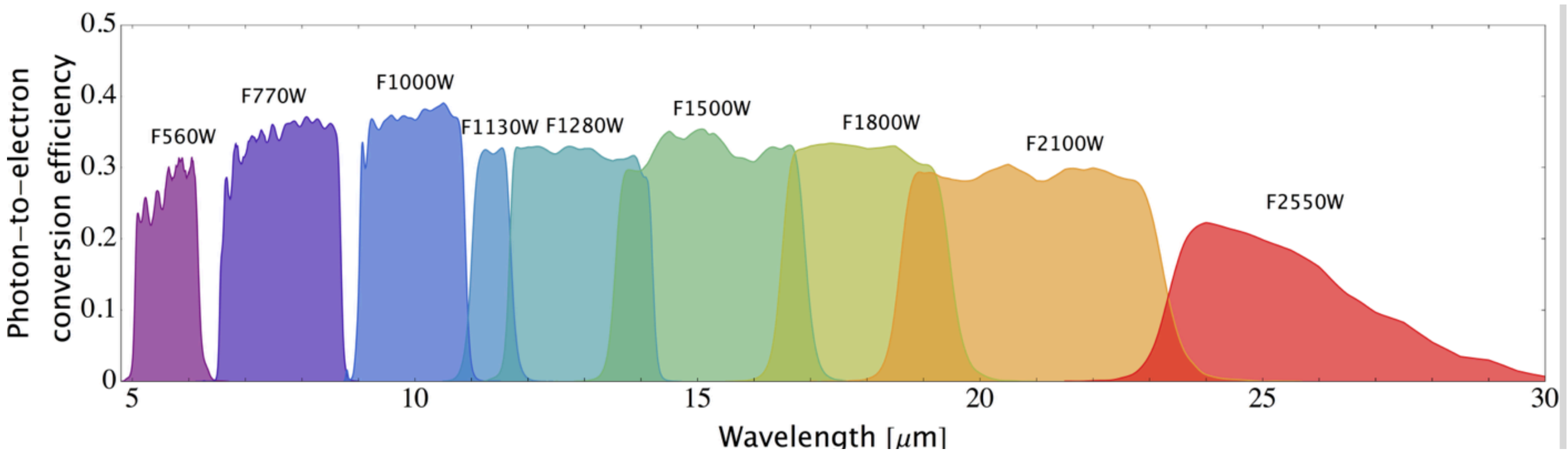
- coordinated parallel to NIRCam imaging in Cycle 1
- 2.2’ x 2.2’ FoV

NIRISS Filters

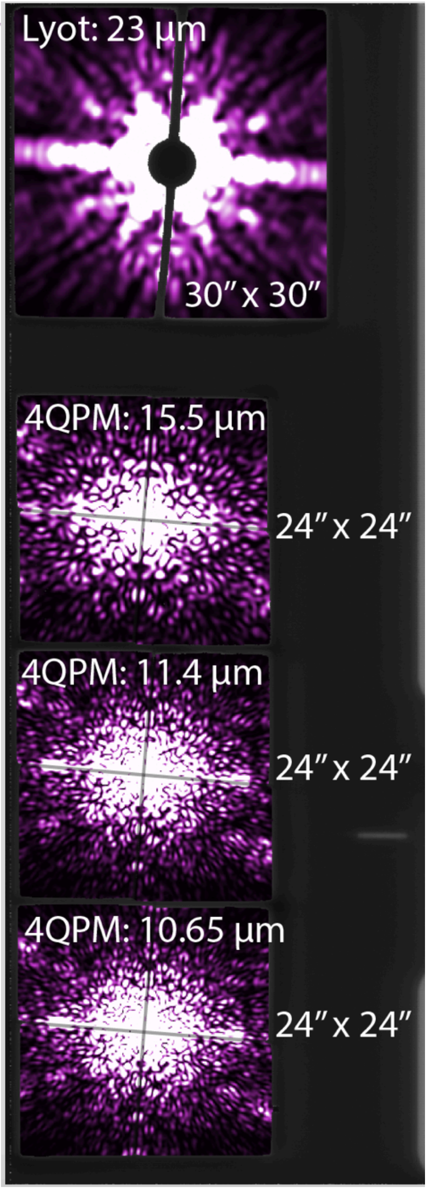


Imaging: MIRI (5.6 – 25.5 μm)





High Contrast Imaging: MIRI Coronagraphy



Wavelength coverage: 10 – 23 µm

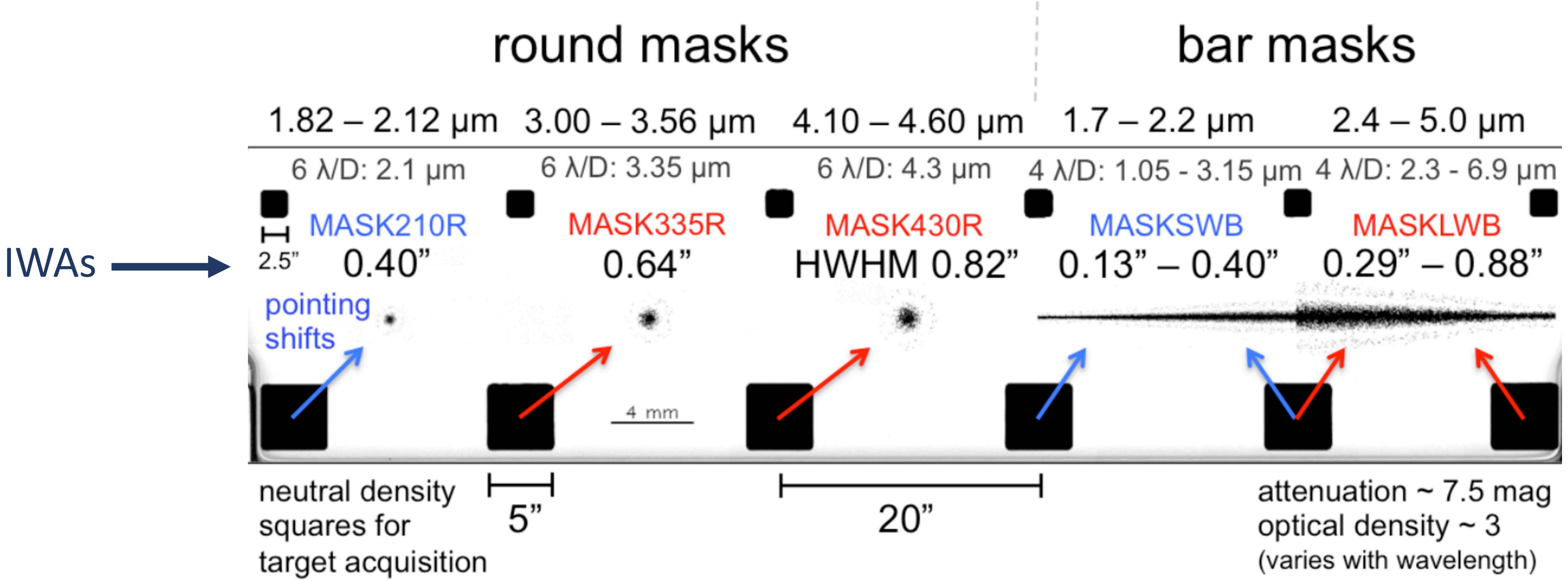
- 4 coronagraphic masks
  - Lyot coronagraph (IWA* ~ 2.16" @ 23 µm)
    - great contrast outside occulting spot → extended objects (debris disk outer regions, AGN ionization cones)
  - 4-quadrant phase mask (IWA ~ 0.34" – 0.49" @ 10-16 µm)
    - optimized for smaller separations (e.g., exoplanets, inner regions of debris disks)

*IWA: inner working angle

- smallest angular separation between host & companion that is detectable

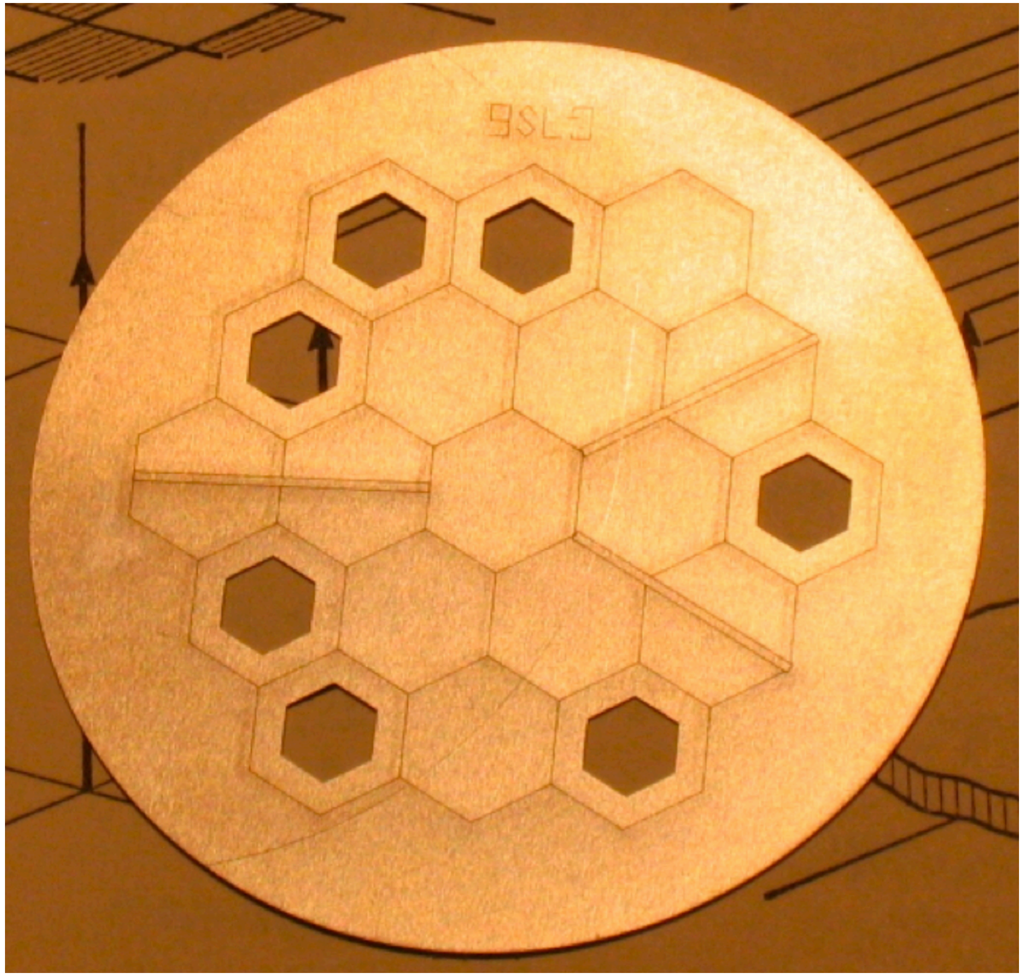
High Contrast Imaging: NIRCam Coronagraphy

Wavelength coverage: 2 – 5 μm



High Contrast Imaging: NIRISS Aperture Masking Interferometry

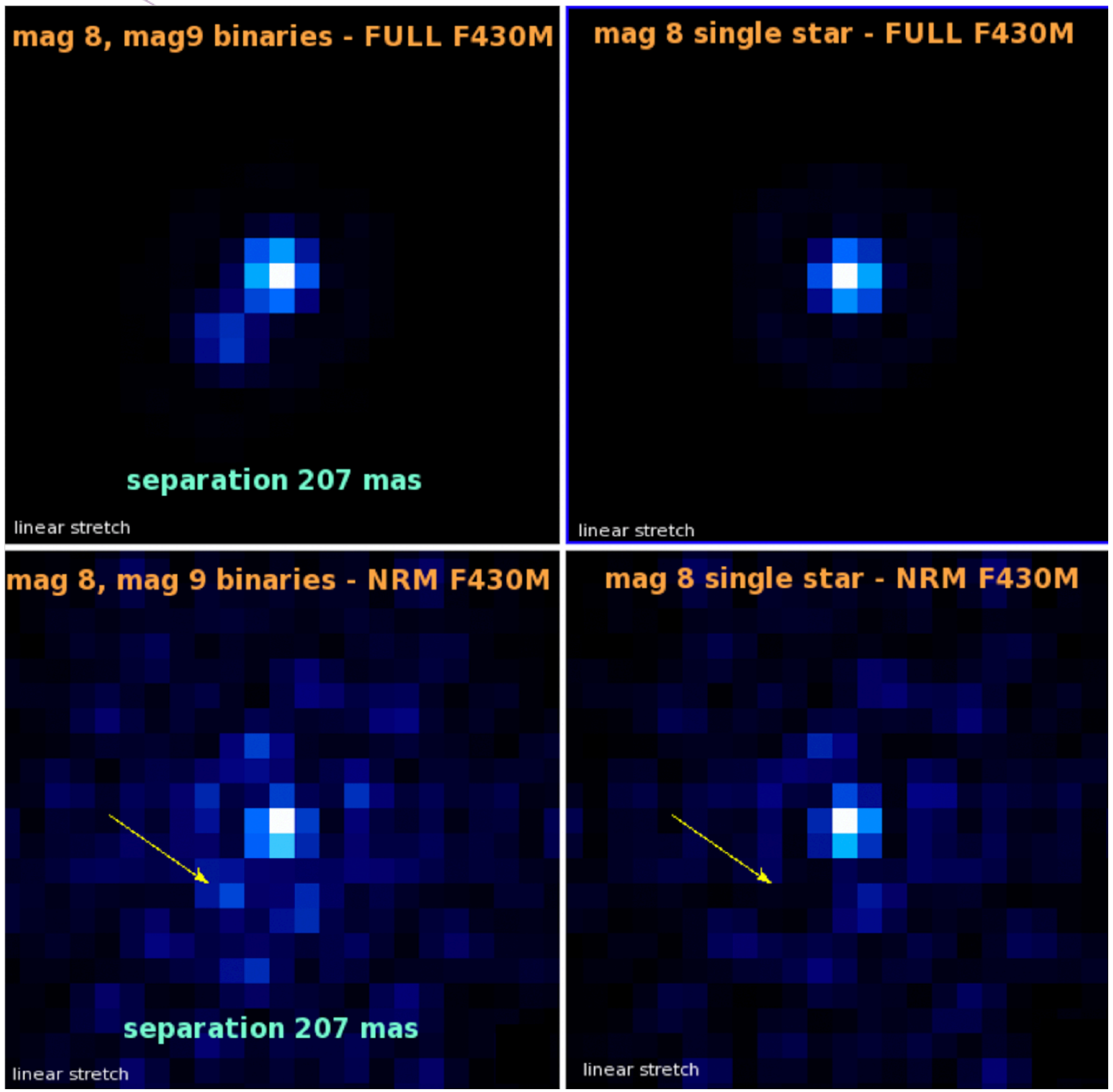
Non-Redundant Mask



Wavelength coverage: 2.8 – 4.8 µm

- resolve separations 70 – 400 mas for contrast ratios of ~10^{-4}
- See D. Thatte's poster Jan 7; 372.12

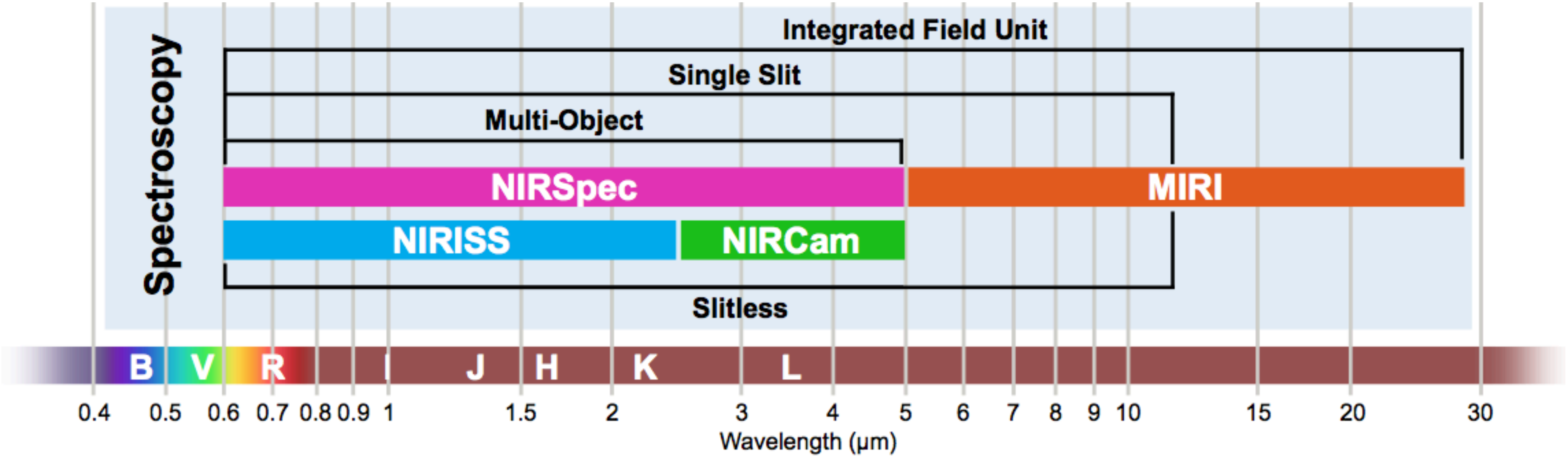
High Contrast Imaging: NIRISS Aperture Masking Interferometry



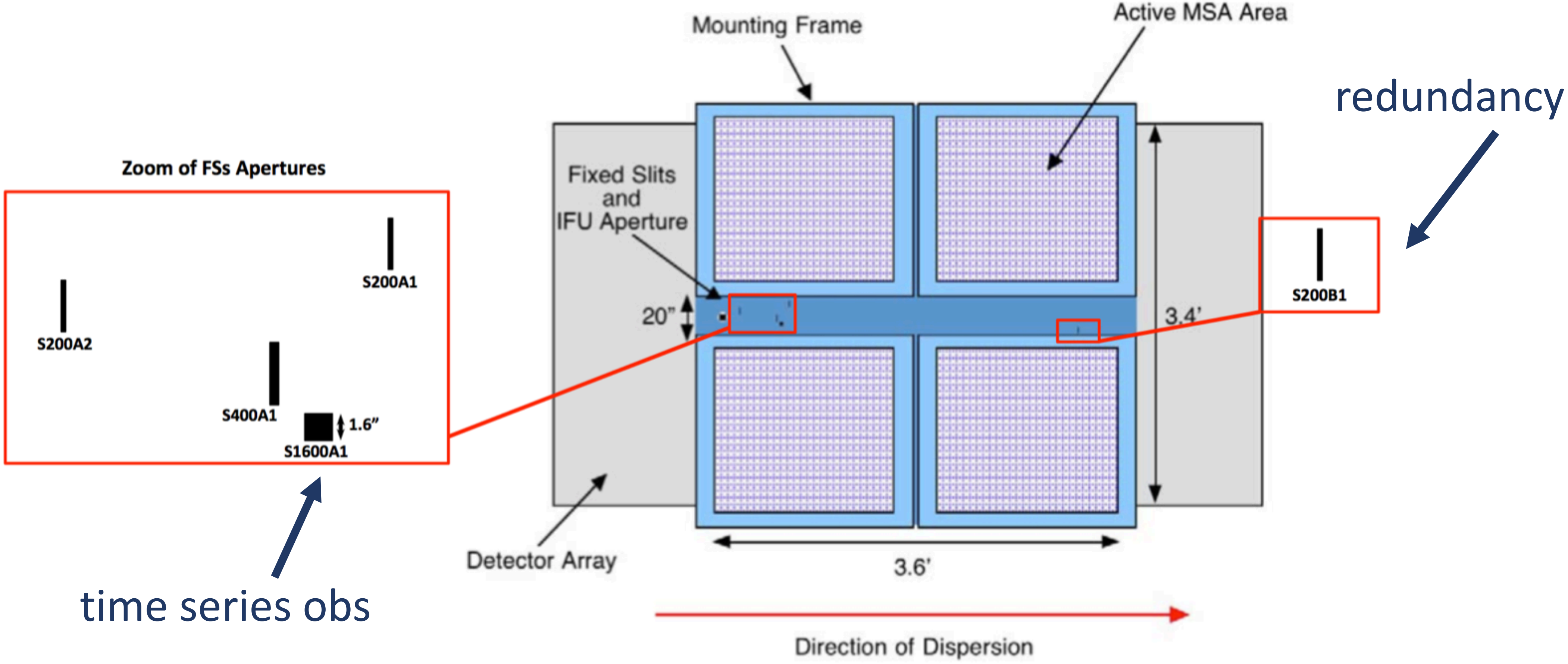
Wavelength coverage: 2.8 – 4.8 µm

- resolve separations 70 – 400 mas for contrast ratios of ~10^{-4}
- See D. Thatte's poster Jan 7; 372.12

Comparison of JWST Instrument Capabilities: Spectroscopy



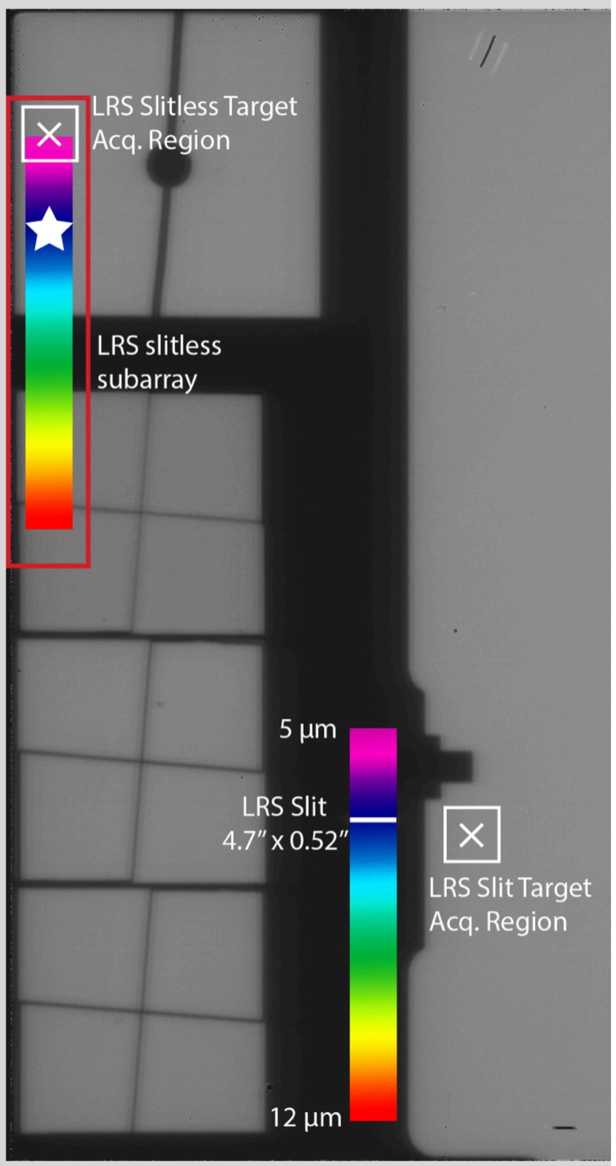
Slit Spectroscopy: NIRSpec (0.6 – 5.3 μm)



Slit Spectroscopy: NIRSpec (0.6 – 5.3 μm)

Disperser-filter combination	Nominal resolving power	Wavelength range † (μm)
G140M/F070LP[1]	~1,000	0.70–1.27
G140M/F100LP		0.97–1.84
G235M/F170LP		1.66–3.07
G395M/F290LP		2.87–5.10
G140H/F070LP	~2,700	0.81–1.27
G140H/F100LP		0.97–1.82
G235H/F170LP		1.66–3.05
G395H/F290LP		2.87–5.14
PRISM/CLEAR	~100	0.60–5.30

Slit Spectroscopy: MIRI (Low Resolution Spectroscopy Mode)



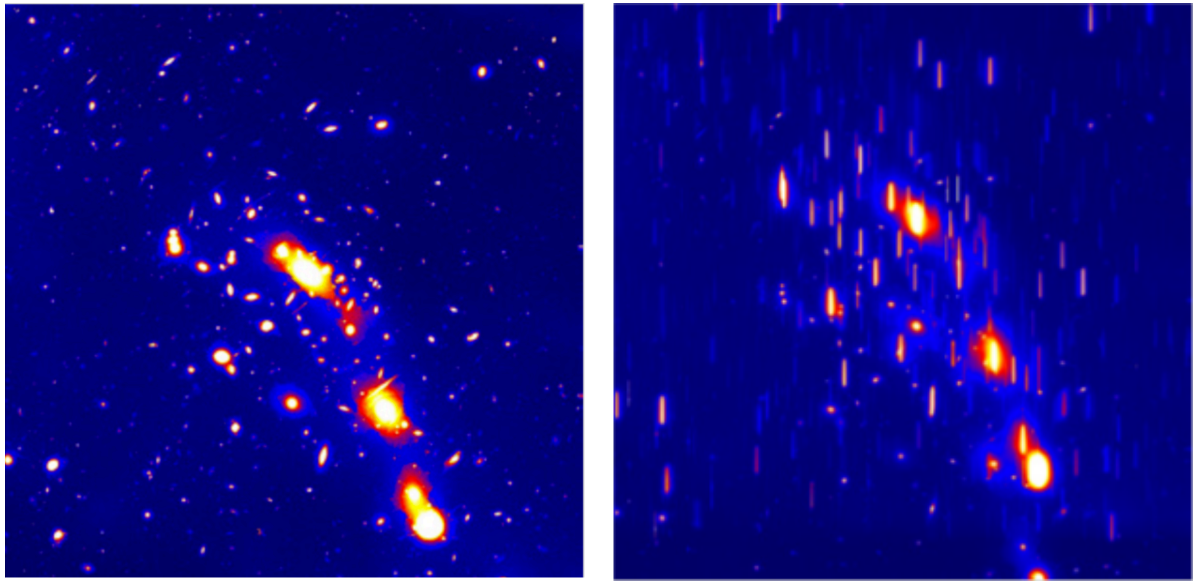
Wavelength coverage: 5 - 12 µm

Resolution: ~40 (5 µm) – 160 (10 µm)

← MIRI LRS slit spectroscopy

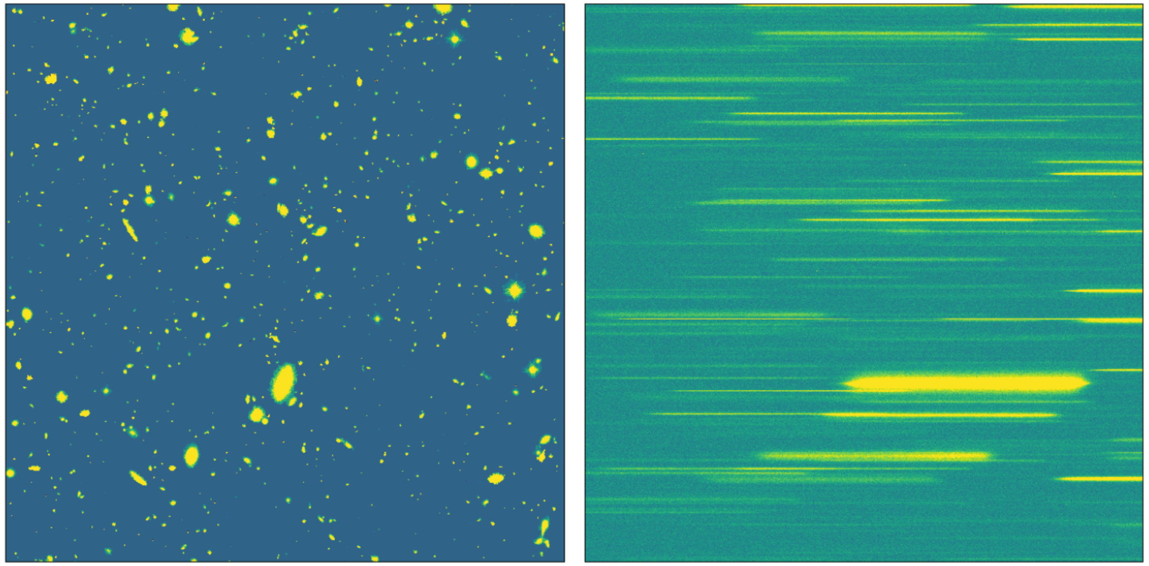
Wide Field Slitless Spectroscopy: NIR Only

NIRISS: 0.8 – 2.2 µm
Resolution: ~150



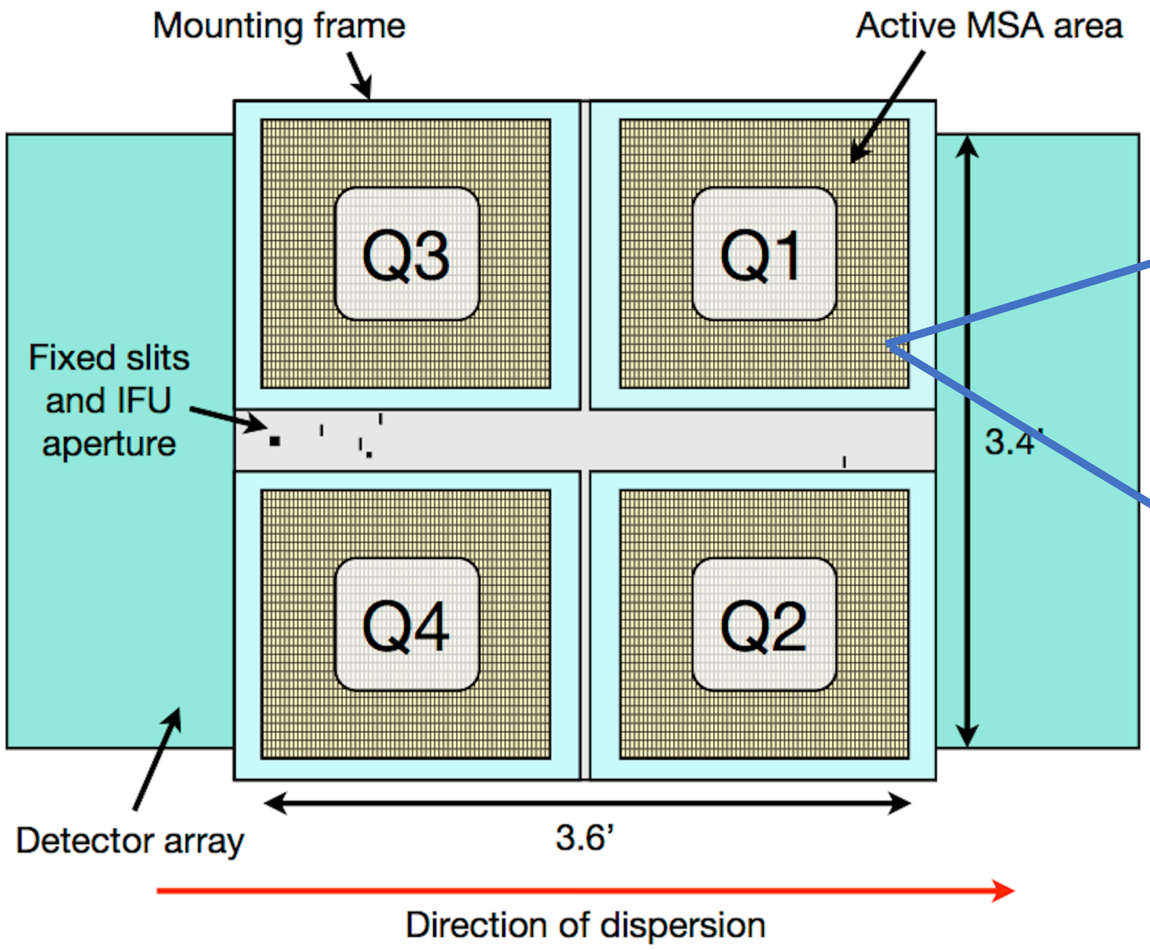
See S. Ravindranath's poster Jan 7; 372.11

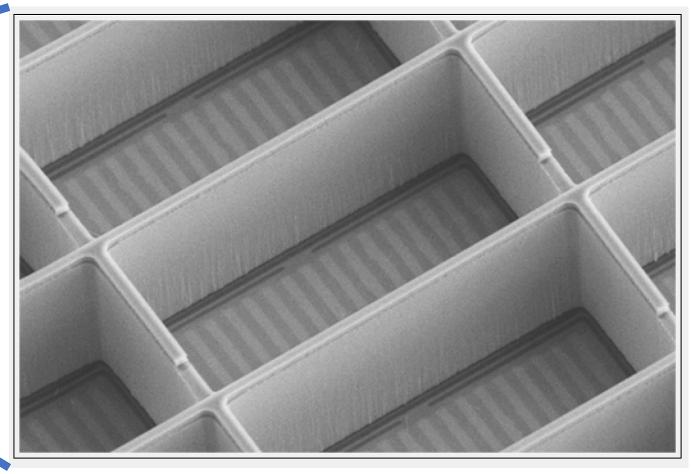
NIRCam: 2.4 – 5 µm
Resolution: ~1600



Multi-Object Spectroscopy: NIRSpec (0.6 – 5.3 μm)

Micro-shutter assembly (MSA)



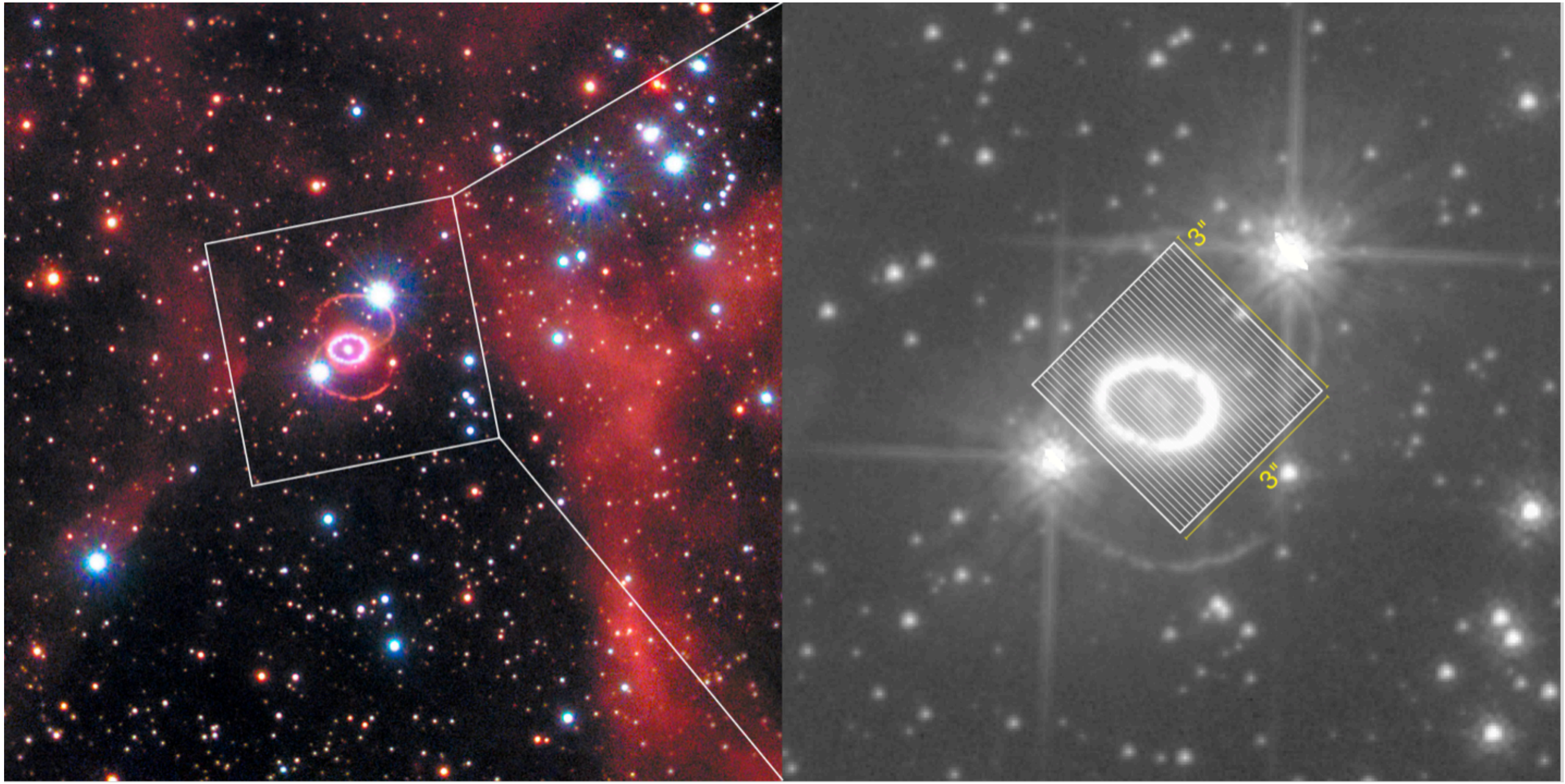


Multi-Object Spectroscopy: NIRSpec (0.6 – 5.3 μm)

- Input catalog needs high astrometric accuracy (5 – 10 mas) from Hubble
    - NIRCam pre-imaging may be required
- NIRSpec MSA Planning Tool (MPT) w/in Astronomer's Proposal Tool (APT) to plan observations
- Resolution: ~100 – 2700

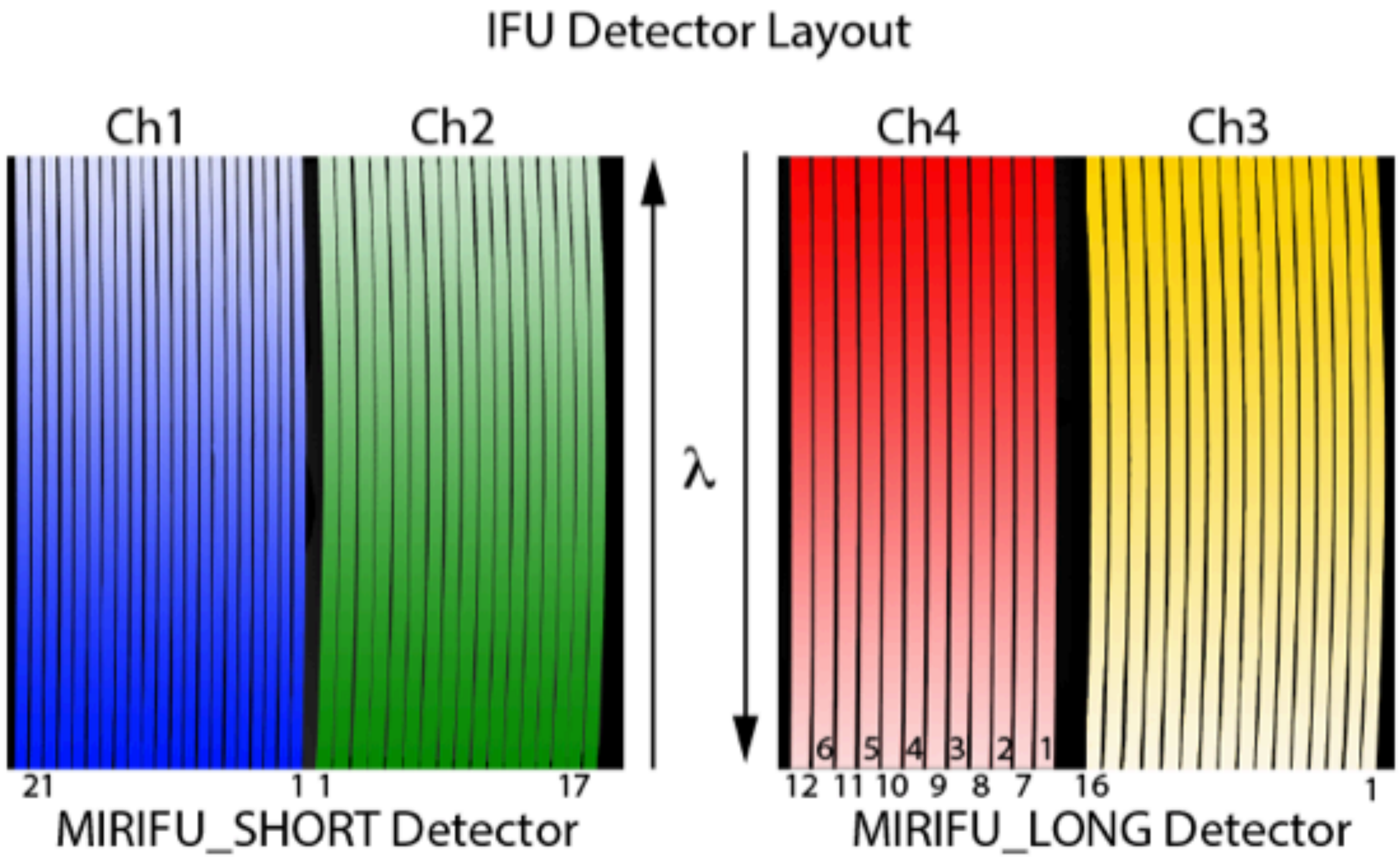
Integral Field Unit Spectroscopy: NIRSpec (0.6 – 5.3 μm)

3” x 3” FOV split into 30 slices → 0.1” x 0.1” spatial element



Integral Field Unit Spectroscopy: MIRI (4.9 – 28.3 μm)

Medium Resolution Spectroscopy (MRS)

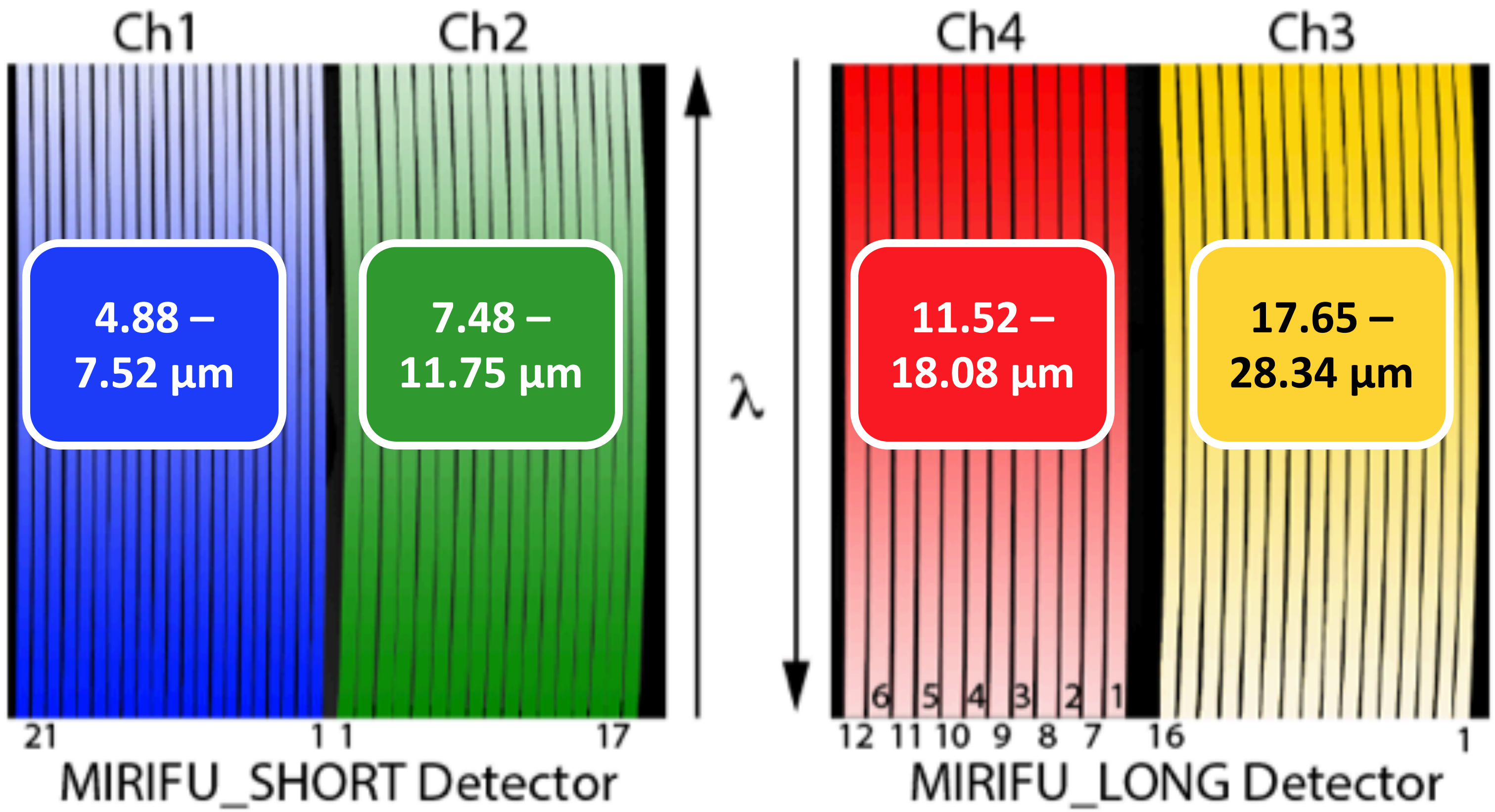


# of slices

Integral Field Unit Spectroscopy: MIRI (4.9 – 28.3 μm)

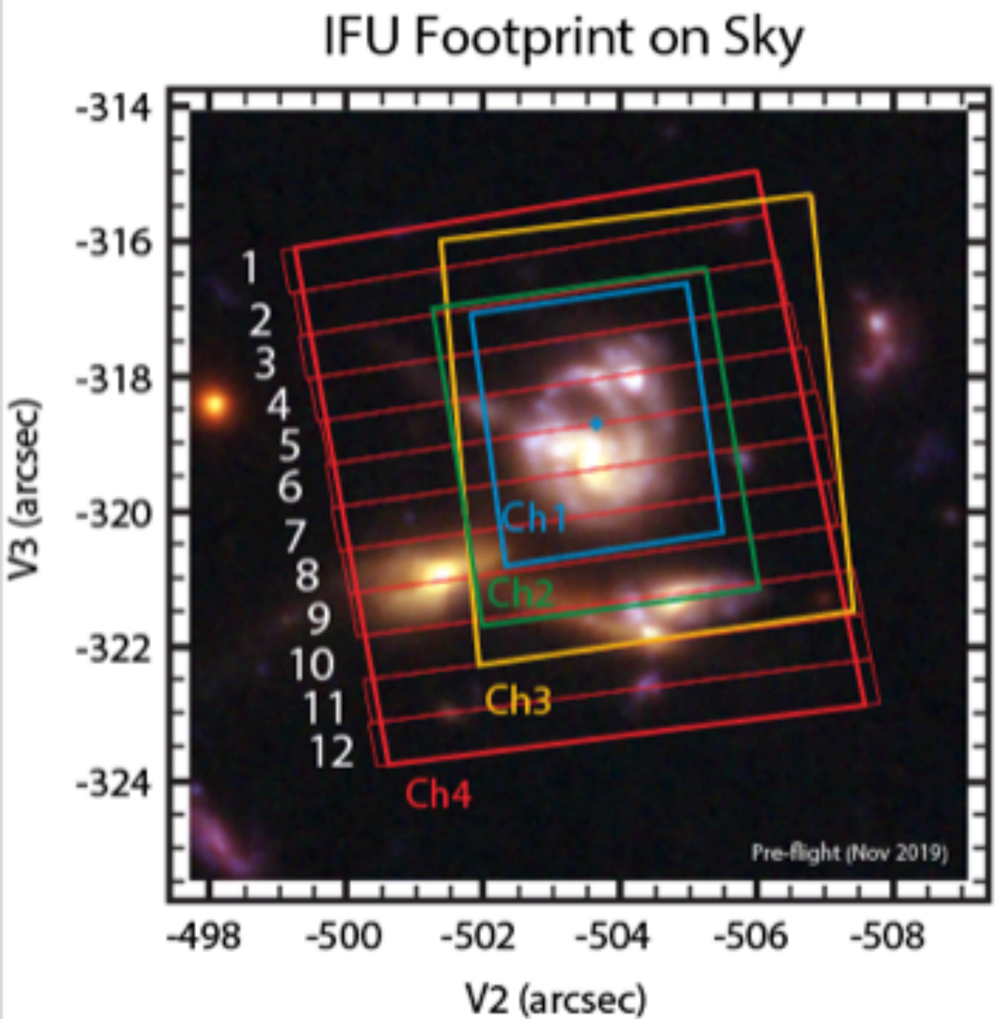
Medium Resolution Spectroscopy (MRS)

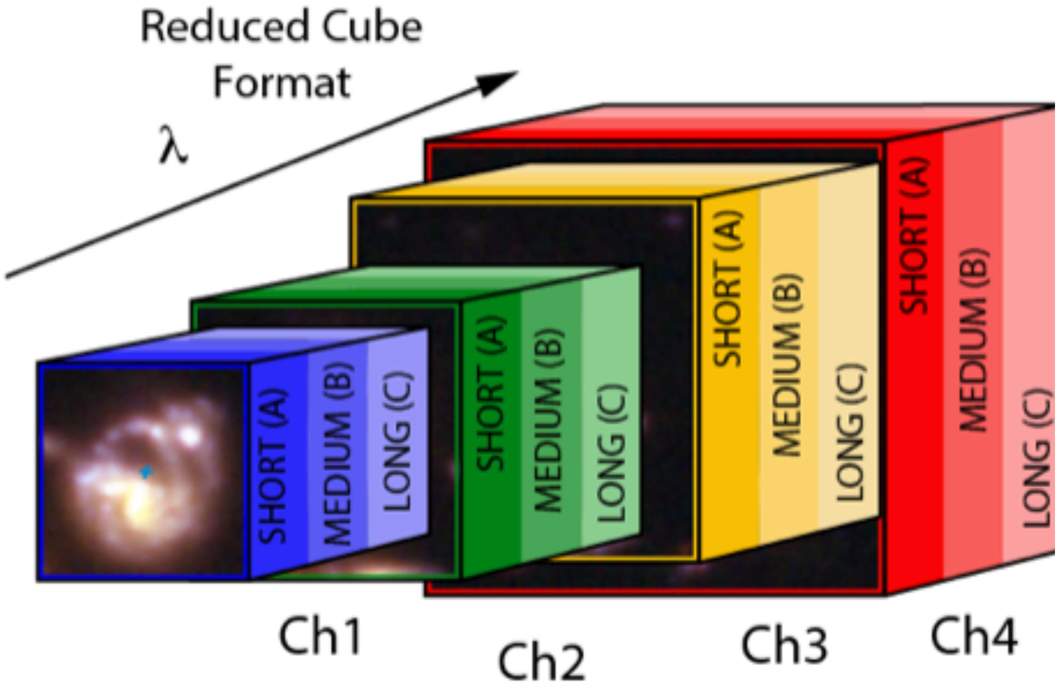
~1/3 of λ range in channel can be observed in 1 exposure (short, medium, long)



Integral Field Unit Spectroscopy: MIRI (4.9 – 28.3 μm)

Medium Resolution Spectroscopy (MRS): resolution ~3000 (5 μm) – 1500 (28 μm)





Time Series Observations: NIR Spectroscopy

NIRISS Single Object Slitless Spectroscopy (SOSS)

- 0.6 – 2.8 µm
- Resolution: ~700

NIRCam Grism Time Series Observations

- 2.4 – 5.0 µm
- Resolution: ~1600

NIRSpec Bright Object Time Series (BOTS) Spectroscopy

- 0.6 – 5.3 µm
- Resolution: ~100 - 2700

Time Series Observations: MIRI Spectroscopy

Low Resolution Spectroscopy (LRS)
- 5 – 12 µm
- Slitless mode only
- Resolution: ~40 (5 µm) – 160 (10 µm)

Medium Resolution Spectroscopy (MRS)
- 4.9 – 28.3 µm
- Resolution: ~3000 (5 µm) – 1500 (28 µm)
- No dithering (unlike typical IFU exposures)

JDox

https://jwst-docs.stsci.edu

James Webb Space Telescope User Documentation

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- JWST General Science Policies

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- Understanding Exposure Times
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- JWST Duplication Checking
- JWST Observatory Functionality
- JWST Observatory Hardware

Proposing Tools

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- Astronomer's Proposal Tool
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JWST User Documentation Home

Latest JDox Release Information:

Release Date	January 23, 2020
Cycle	1
APT Version	2020.1
ETC Version	1.5

JWST user documentation, informally known as "JDox," is available as a collection of articles. Unlike conventional HST handbooks, JDox is intended as an agile, user-friendly source of information that follows the Wikipedia-like Every Page is Page One (EPPO) philosophy. Our goal is to provide short, focused, well-linked articles that provide the kinds of information found in traditional HST instrument handbooks, data handbooks, and calls for proposals. These articles go on to provide details about the observatory and instruments, descriptions of tools used for proposing, advice on observing strategies, roadmaps that guide users through the proposal preparation process, as well as information about calibration and analysis of JWST data.

Downloadable PDF collections of the documentation are provided as a courtesy, made available and updated when feasible. ***The online documentation is the most up-to-date authority.*** **JDox is made possible by the following contributing authors:**

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Methods articles summarize instrument capabilities

Proposing Opportunities

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- MIRI
- NIRCam
- NIRISS
- NIRSpec

Methods and Roadmaps

- Imaging
- Wide Field Slitless Spectroscopy
- High-Contrast Imaging
- Integral Field Spectroscopy
- Multi-Object Spectroscopy
- Time-Series Observations
- Moving Target Observations
- Parallel Observations
- ToOs

Methods - WFSS example

Main articles: NIRCam WFSS Recommended Strategies, NIRISS WFSS Recommended Strategies
See also: NIRCam WFSS Science Use Case, NIRISS WFSS Science Use Case

Several of the JWST instruments offer a slitless spectroscopic mode. Slitless spectroscopy is particular in that every source in the field results in a dispersed spectra. This mode differs substantially from regular direct imaging observations and slit spectroscopy. Some of the similarities and differences between imaging and slitless observations that can impact observing strategies and planning are discussed below.

JWST slitless spectroscopic modes

Main articles: NIRCam Wide Field Slitless Spectroscopy, NIRISS Wide Field Slitless Spectroscopy

WFSS mode disperses the light of any object that is within the field of view of the instrument. This often results in hundreds, if not thousands of spectra that often overlap in the final observation. This mode is similar to the HST NICMOS, ACS and WFC3 grism observations. NIRCAM and NIRISS both implement WFSS using two different grisms that disperse the spectra either horizontally or vertically onto the detector. This allows for the dispersed spectra to overlap in completely different manner without having to change the orientation of the whole JWST telescope.

The following table summarizes the WFSS modes of NIRCAM and NIRISS.

Table 1. Summary of WFSS modes in NIRCAM and NIRISS

Instrument	Wavelength (μm)	Pixel scale (mas/pix)	R	Field of view	GRISMs
NIRCam	2.4–5.0	65	~1,600 at 4 microns	2.21' × 2.21'	GRISMR (horizontal) GRISMC (vertical)
NIRISS	0.8–2.2	65	~150 at 1.4 microns	2.2' x 2.2'	GR150C (horizontal) GR150R(vertical)

Roadmaps! WFSS example

Step-by-Step Guidelines

1. Choose the instrument (NIRISS, NIRCam, or both) to use for the science case, based on the wavelength coverage.
   NIRISS Wide Field Slitless Spectroscopy (0.8–2.2 µm)
   NIRCam Wide Field Slitless Spectroscopy (2.4–5.0 µm)

2. Choose the blocking filters that cover the wavelengt
   NIRISS Filters
   NIRCam Filters

3. Check the the direct image and grism (line and conti
   NIRISS Sensitivity
   NIRCam Sensitivity

4. Choose one or both of the orthogonal grisms. Use of
   discussed in the recommended strategies articles lir
   NIRISS GR150 Grisms
   NIRCam Grisms

5. Decide on the dither pattern required to mitigate de
   operates at shorter wavelengths where the PSF is ur
   NIRISS WFSS Dithers
   NIRCam Wide Field Slitless Spectroscopy Dithers

6. Decide whether mosaicking is required to cover the
   NIRISS mosaics
   NIRCam mosaics

7. Decide the readout pattern to use.
   NIRISS Detector readout patterns
   NIRCam Detector readout patterns

8. Use the Exposure Time Calculator (ETC) to determine the exposure parameters for the direct images and for the dispersed images from the grisms.
   JWST ETC Imaging Aperture Photometry Strategy
   JWST ETC Aperture Spectral Extraction Strategy

9. Fill out the Astronomers Proposal Tool (APT) for NIRISS WFSS or NIRCam WFSS.
   NIRISS Wide Field Slitless Spectroscopy APT template
   NIRCam Wide Field Slitless Spectroscopy APT template

10. Define mosaic parameters in APT (if needed by science program).
    JWST APT Mosaic Planning

11. Follow the instructions for coordinated parallels if attaching parallels to the WFSS prime observations.
    JWST APT Coordinated Parallel Observations
    Coordinated Parallels Roadmap

Example Science Programs available as guides

Instruments

- MIRI
- NIRCam
- NIRISS
  - Overview
  - Observing Modes
  - Instrumentation
  - Operations
  - Predicted Performance
  - APT Templates
  - Observing Strategies
    - WFSS
    - SOSS
    - AMI
    - Imaging
  - Example Science Programs
- NIRSpec

- Example Science Programs
  - AMI Observations of Extrasolar Planets Around a Host Star
  - SOSS Time-Series Observations of HAT-P-1
  - WFSS with NIRCam Parallel Imaging of Galaxies in Lensing Clusters
    - ETC Instructions
    - APT Instructions

4 instruments → 18 observing modes*

- JDox (https://jwst-docs.stsci.edu) is *your* resource for all your JWST instrument capability needs
- JWST Proposing Open House Part 1: Integral Field Unit Observing
  - Jan 5th 9:30 – 11:30 AM
- JWST Proposing Open House Part 2: Grism Observing
  - Jan 6th 9:30 – 11:30 AM
- JWST Proposing Open House Part 3: NIRSpec Micro-shutter Array
  - Jan 7th 9:30 – 11:30 AM
- Jan 7th poster presentations: 372.11 (Ravindranath et al.), 372.12 (Thatte et al.)

*Standard imaging & slit spectroscopy; high contrast imaging; wide field slitless ("grism") spectroscopy; multi-object spectroscopy; integral field unit spectroscopy; time series observations (imaging & spectroscopy)

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